ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

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LEC
Laboratory for Energy Conversion



Characterization of a High Brightness Sn droplet EUV Source

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Switzerland.

Outline

- Laboratory for Energy Conversion, ETH.
- Applied Laser Plasma Science (ALPS) Facility.
- Droplets, Dispenser and Triggering.
- Pinhole camera and spotsize measurements.
- High Brightness Collector and I.F. measurements.
- EUV radiation measurements and results.
- Adlyte Ltd. Products: Debris mitigation results from HPS.
- Acknowledgements

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Laboratory for Energy Conversion



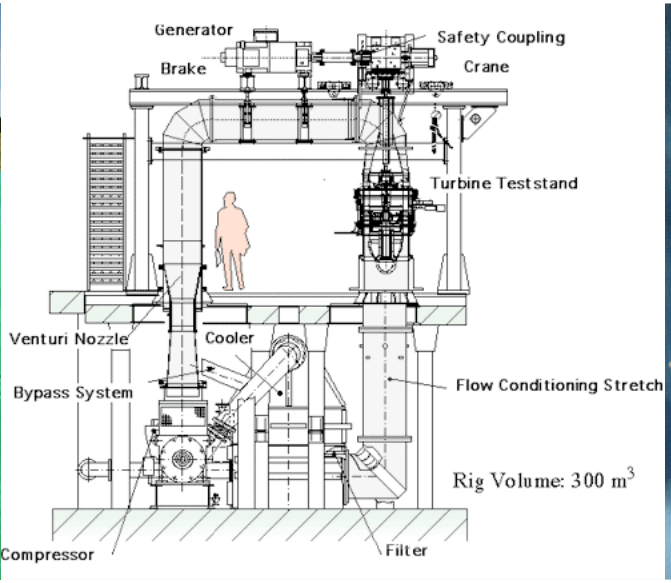






Figure 1:2 Sensor FRAP Probe with 1.8mm tip outer diameter of LEC.

People:

•75 members of staff including PhD students, post-docs, Msc students, Electrical engineers and Workshop technicians.

Fields of Research:

•Power, Energy and Turbomachinery
•Applied Laser Plasma Science
•Environmental and Renewable Energy
•Instrumentation

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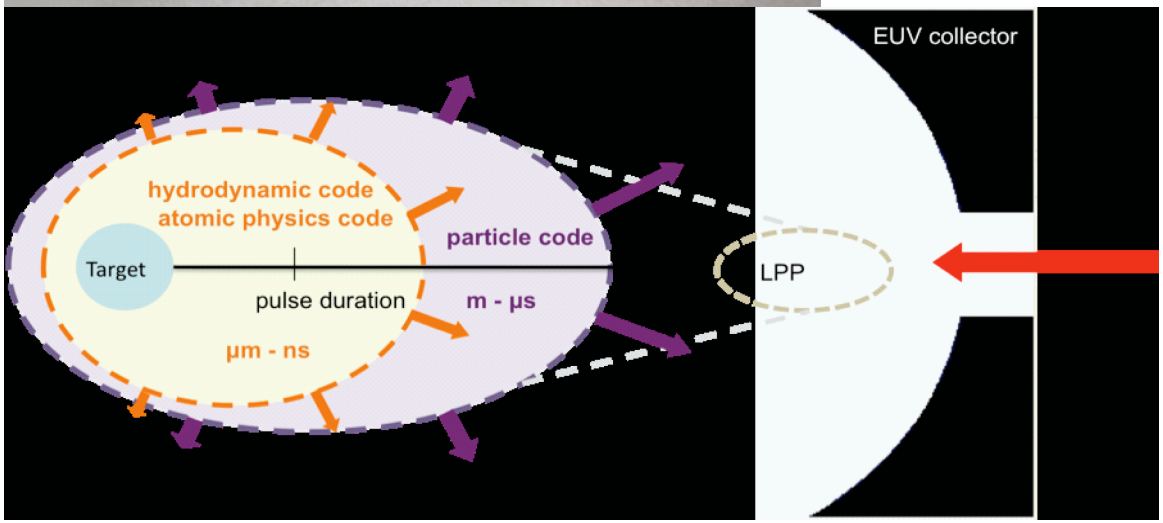
Applied Laser Plasma Science (ALPS) Facility



Laboratory:

•AO16 Nd:YAG Laser, 1064 nm, 20 kHz, 1.6 kW.

•Entire system automated from a single control unit.

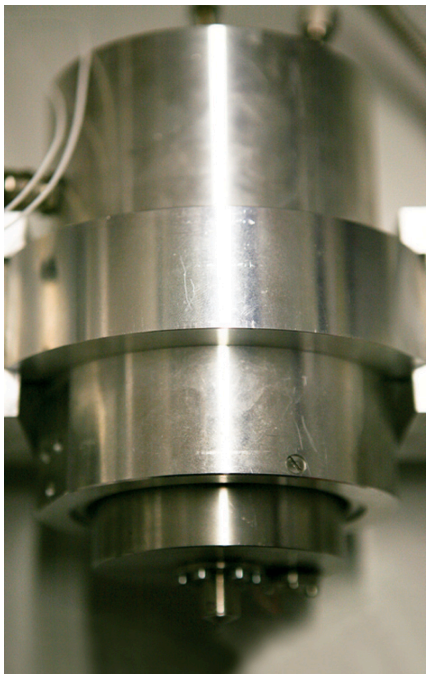


Computational studies:

•2-D/axisymmetric hydrodynamic-particle code used to model plasma expansion from laser-droplet interaction up to the collector optic.

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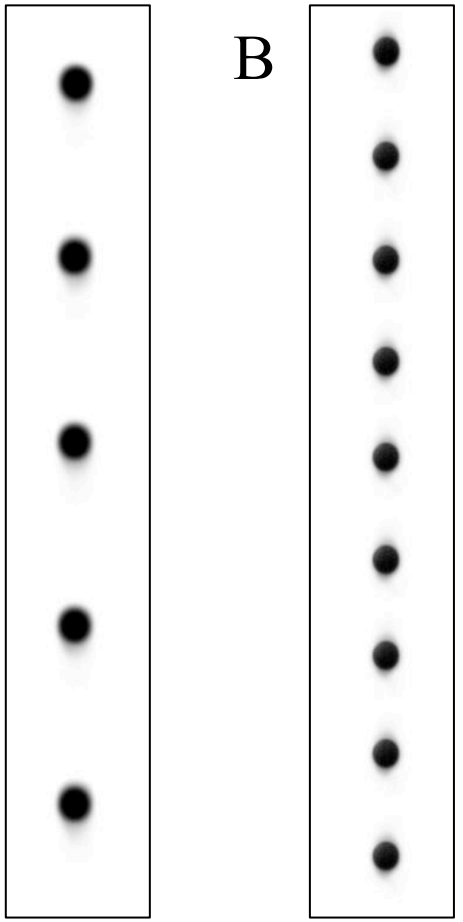
Droplet Dispenser

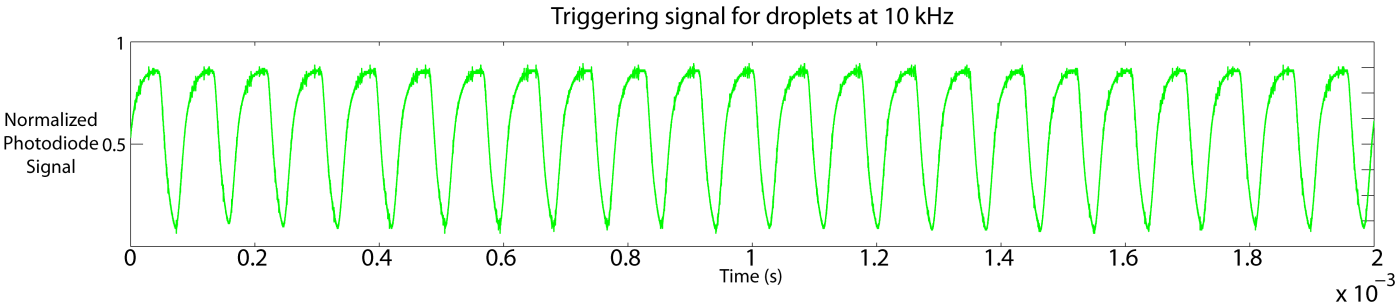


- Images recorded using Xe flash and macroscope.
- Single droplet exposure.

- (A) 20kHz, 3bar backpressure, 35um nozzle

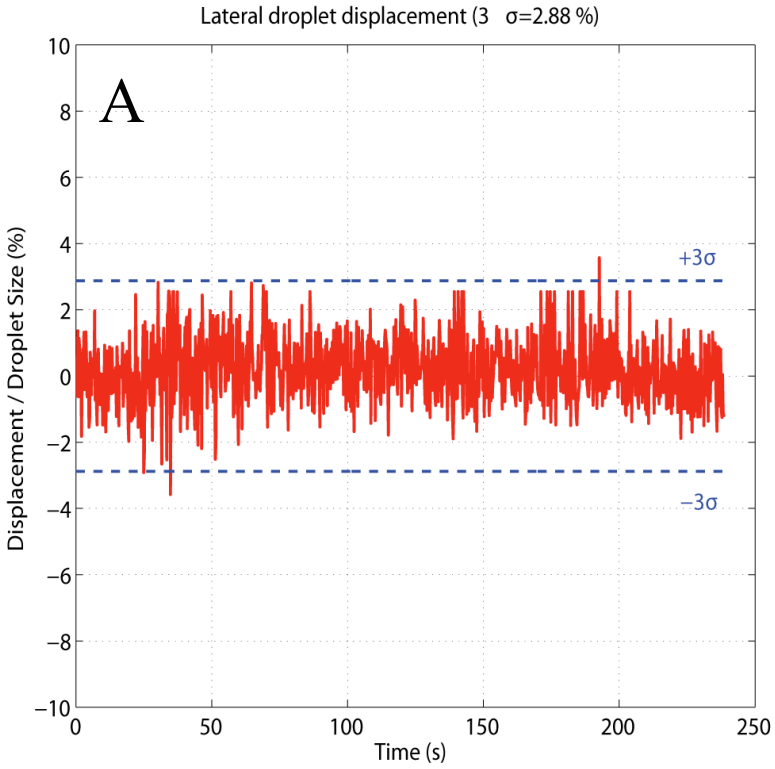
- (B) 50kHz, 8bar backpressure, 35um nozzle

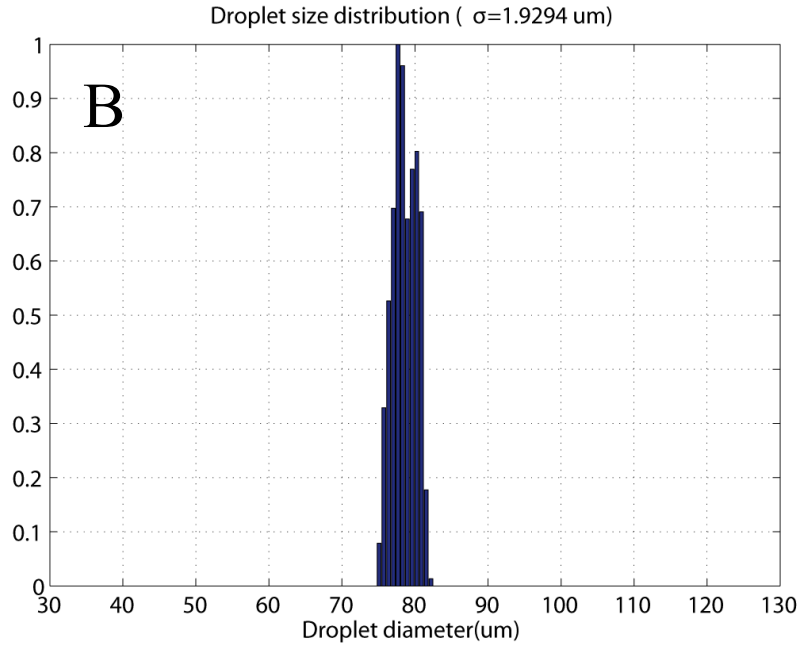




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Droplet Stability



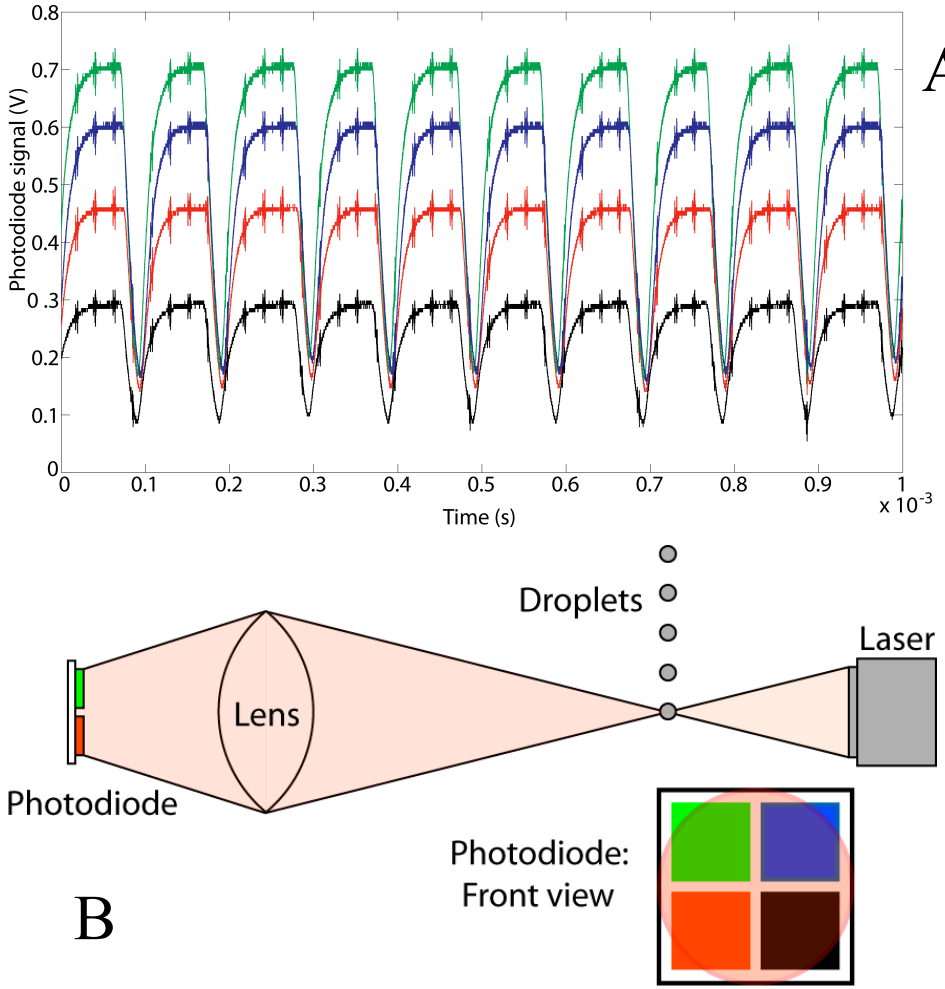


(A) Lateral droplet to droplet temporal stability for 35µm nozzle, operated at 20kHz.
Relative lateral motion of the droplets is limited to +/- 2.88%.

(B) Droplet size distribution for 35µm nozzle. The standard deviation of the size distribution is 1.9 µm.

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Droplet by droplet triggering



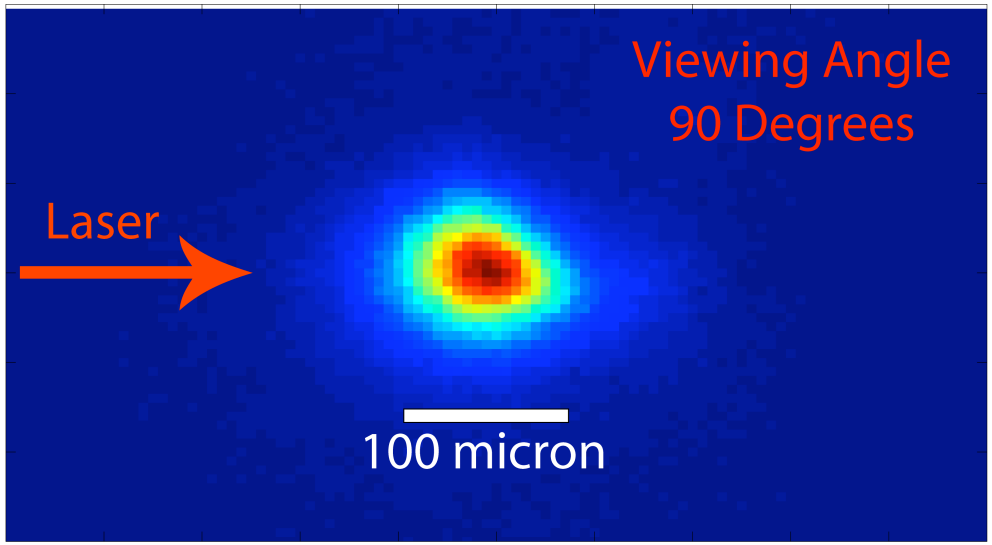
Signals recorded at 10 kHz using a quadrant photodiode.

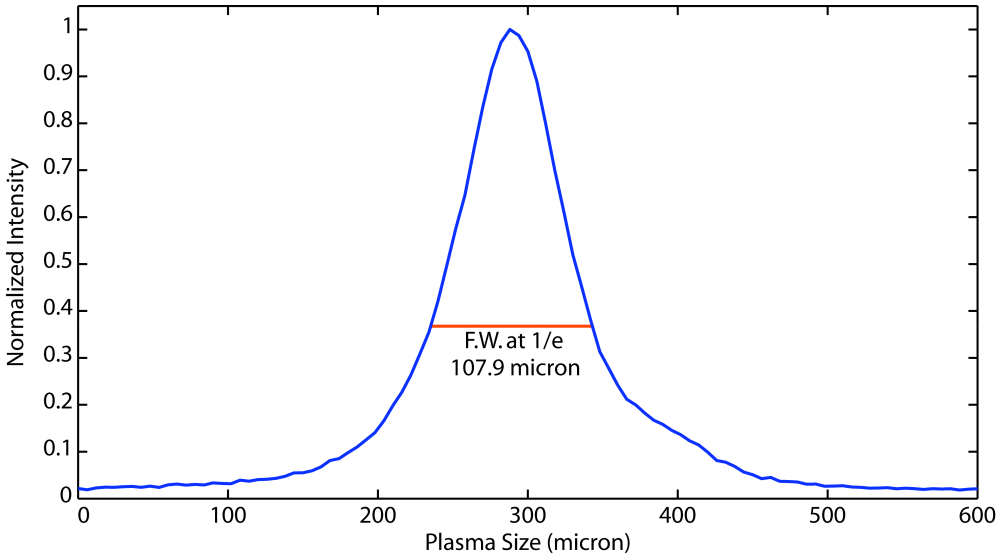
A: Droplets in phase and centered on the 4 photodiodes

B: Layout of the detector.

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Pinhole Camera and Spotsize Measurements

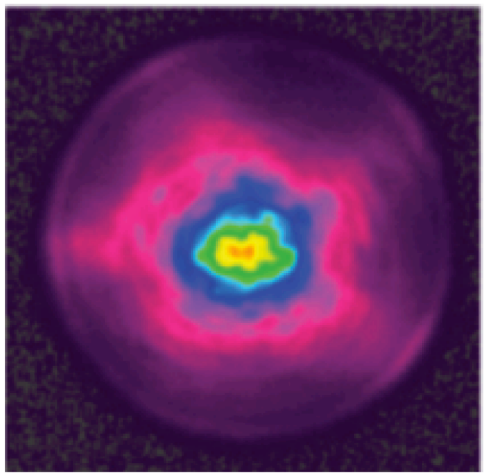




Pinhole Camera:

- 50 micron aperture
- Resolution: 6 microns per pixel

Laser spot at focus

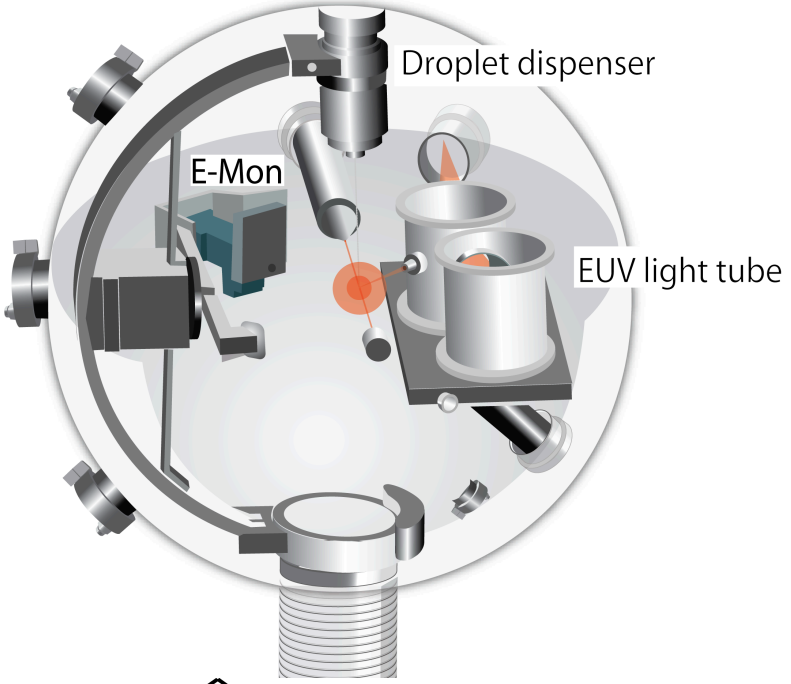


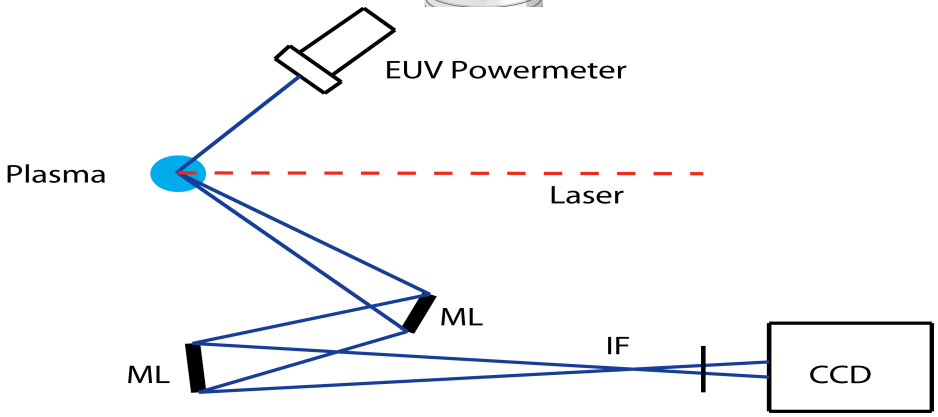
Focused laser spotsize:
78 micron

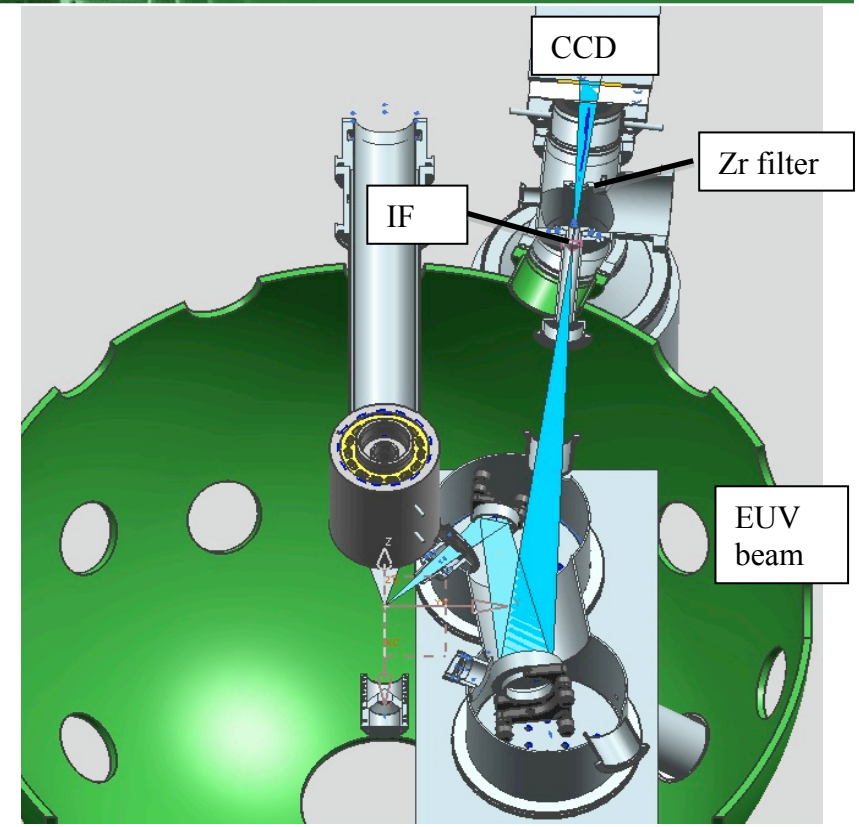
Spiricon Image of the AO16 laser pulse.

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High Brightness Collector



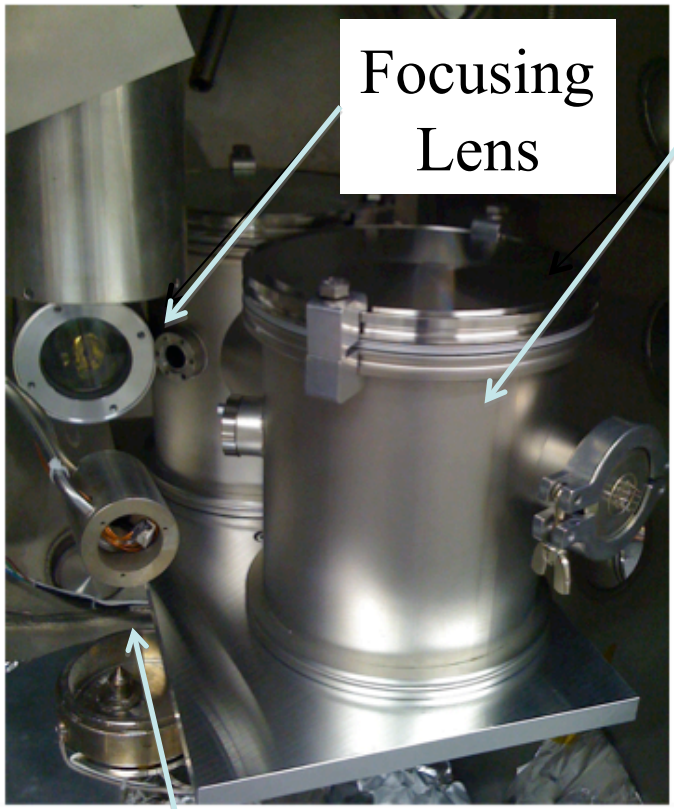




CCD Camera (Pixis 100B) is used to measure the radiation pattern at 169.4 mm after the IF.

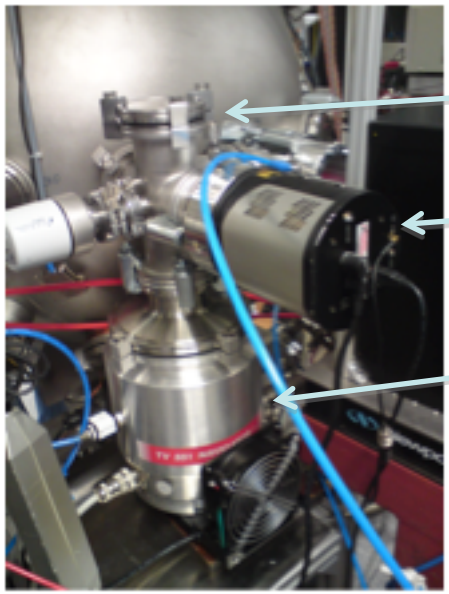
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LPS – IF Tube Setup



IF Tube

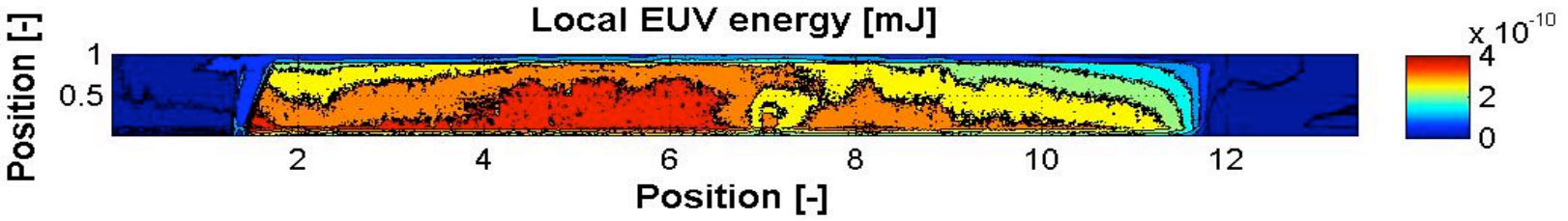


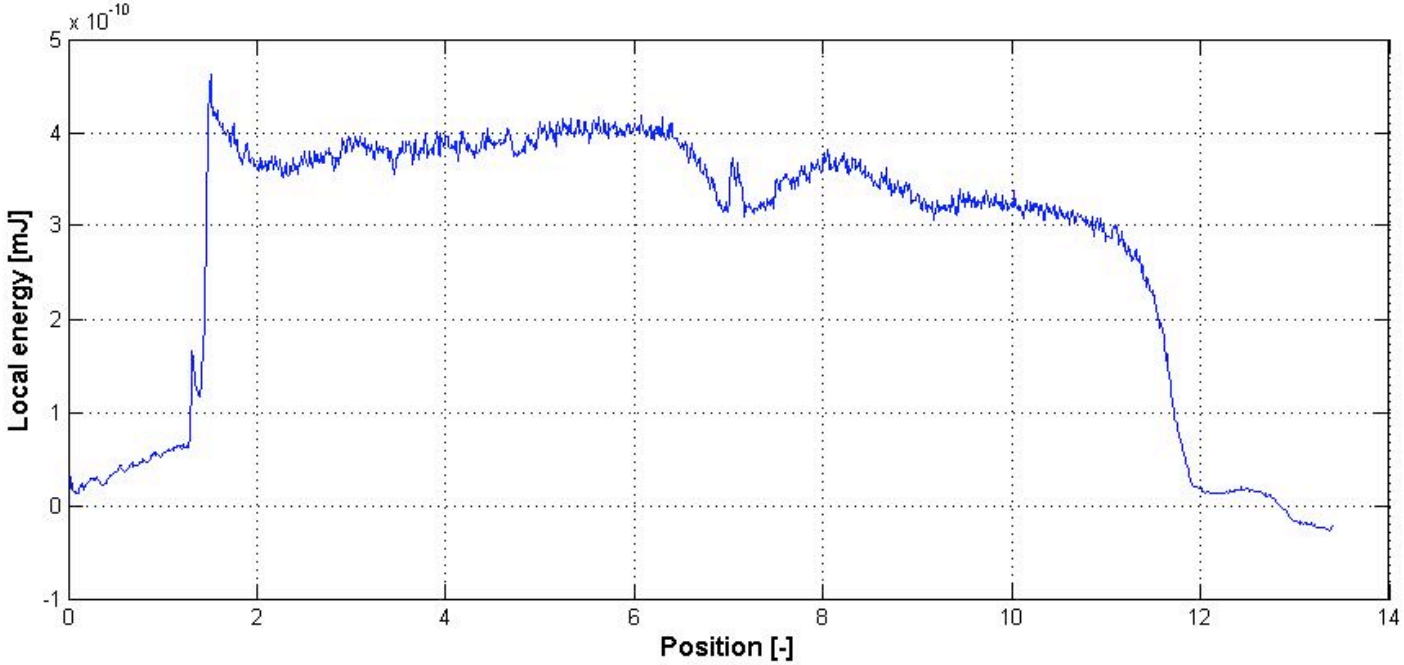


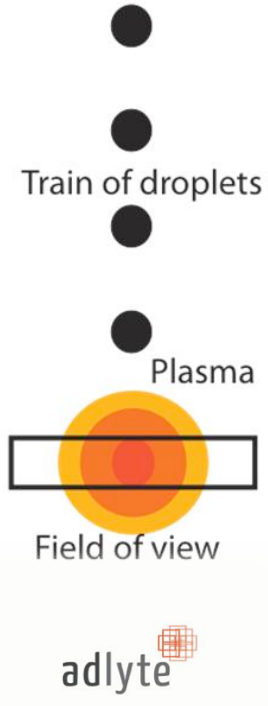
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IF Power Measurements

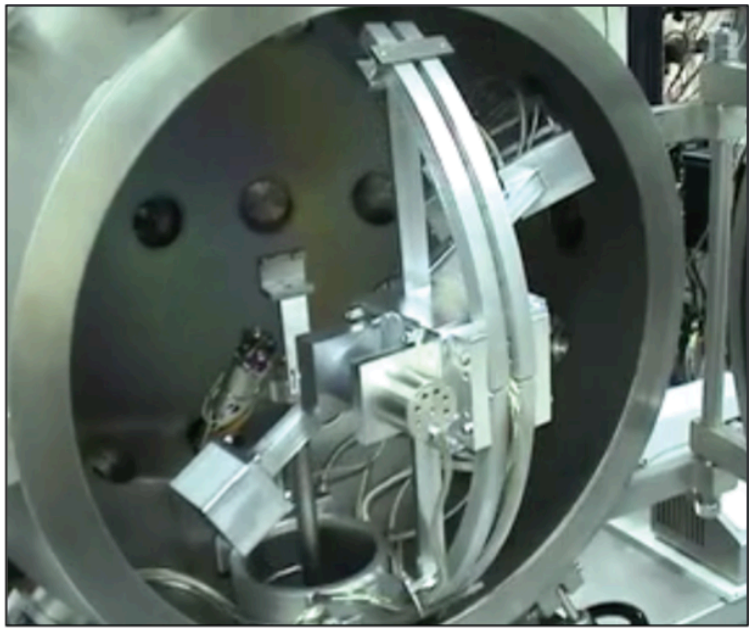
Laser operation at 6 kHz. Power Density 1.5 x 10^{11} W/cm^2. Image integrated over 4 plasmas.



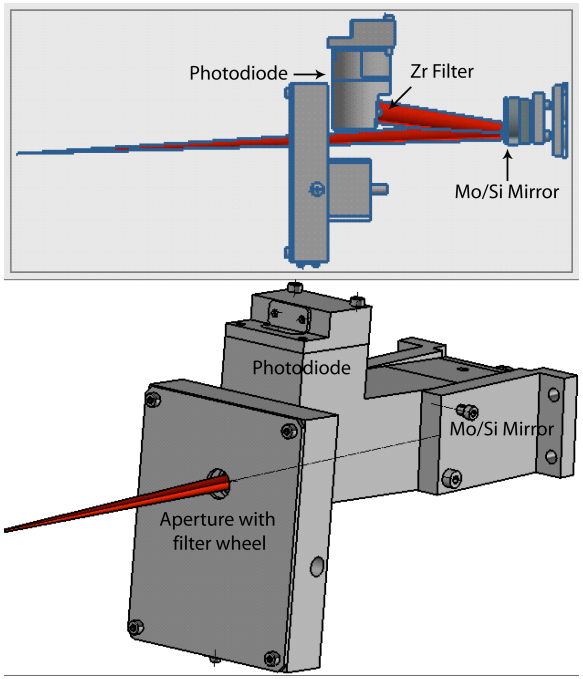




EUV Radiation Measurements



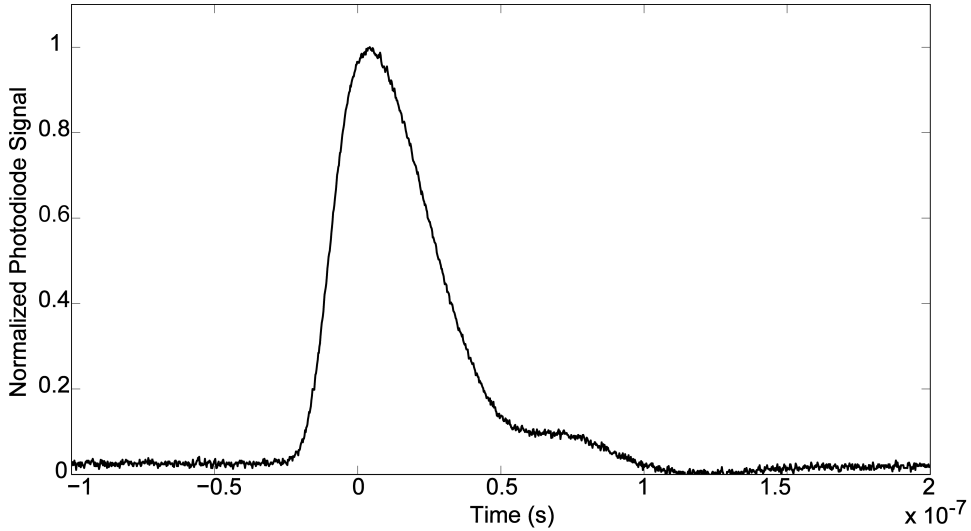
E-Mon located on a robot arm, capable of measuring the source over approximately 4 pi Sr.



Scientec Energy Monitor.
100 nm Zr filter installed in front of the photodiode.
3 mm aperture
Aperture to source: 15 cm

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EUV Radiation Measurements



EUV signal from energy monitor.

6 kHz tin droplet irradiated with Nd:YAG laser.

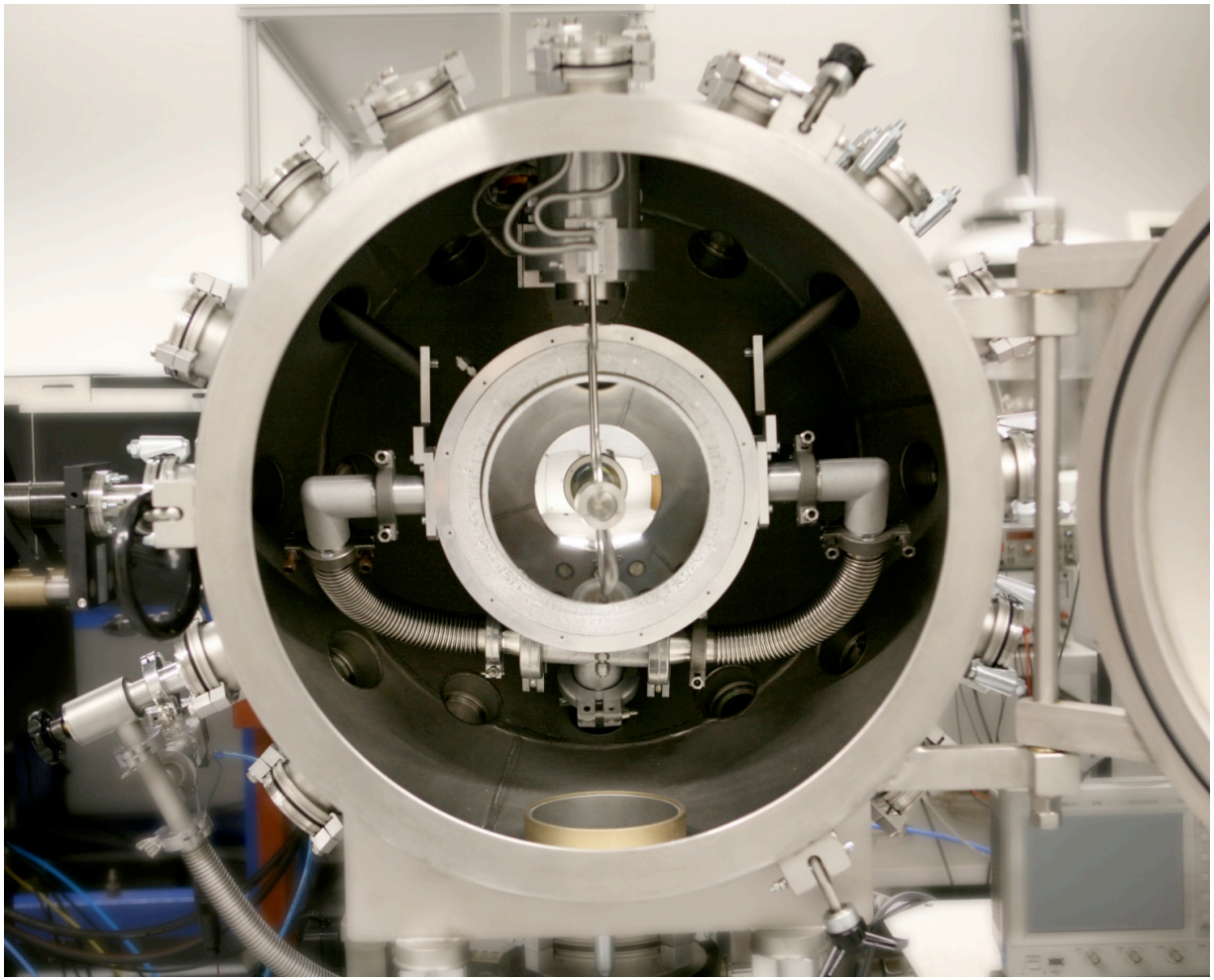
Parameters	Measured
Laser power on target (W)	1100
Laser Frequency (kHz)	6
Laser focal spot size (um)	78
EUV source size (um)	107 at FW at 1/e
Average Conversion efficiency (%)	0.95%
Source brightness (W/mm^2/sr)	≈ 200

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Ongoing Work

- Present Science and Technology Development continuing.
- To commercialize, an ETH spin-off company called Adlyte Ltd was formed in 2009.
- Currently Adlyte is working with customers in the metrology and inspection fields.

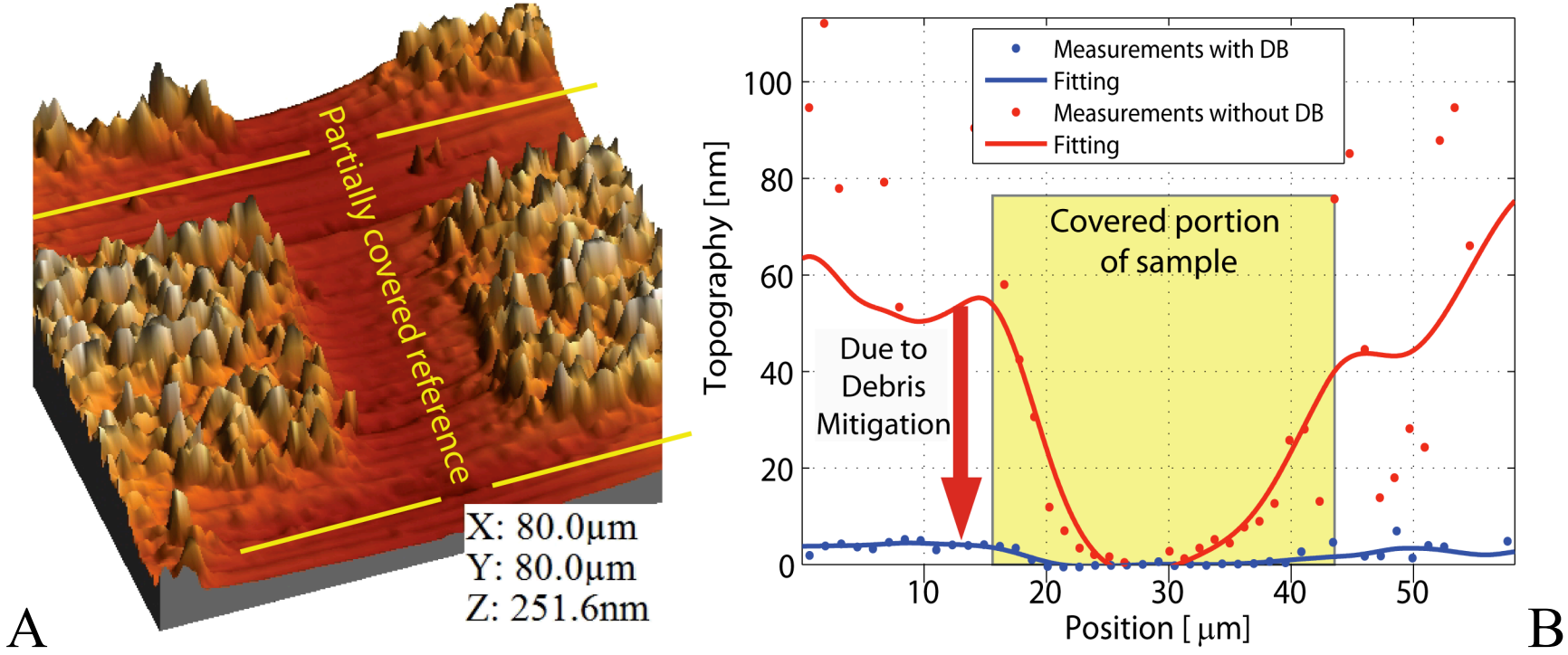
High power EUV source (HPS)



- Large solid angle, 4 sr.
- High IF power.
- Integrated debris mitigation system.
- Integrated collector cooling.

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Debris Mitigation



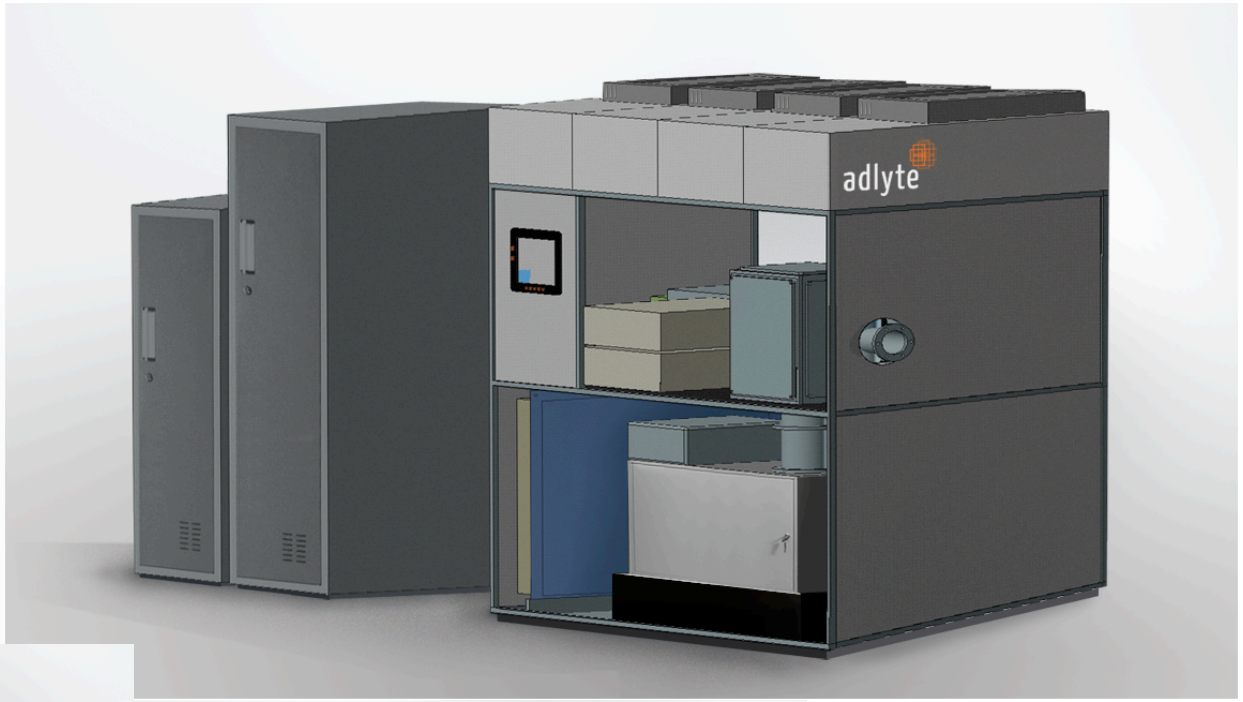
A: AFM measurement sample without debris mitigation.
B: Comparison of samples with and without debris mitigation.

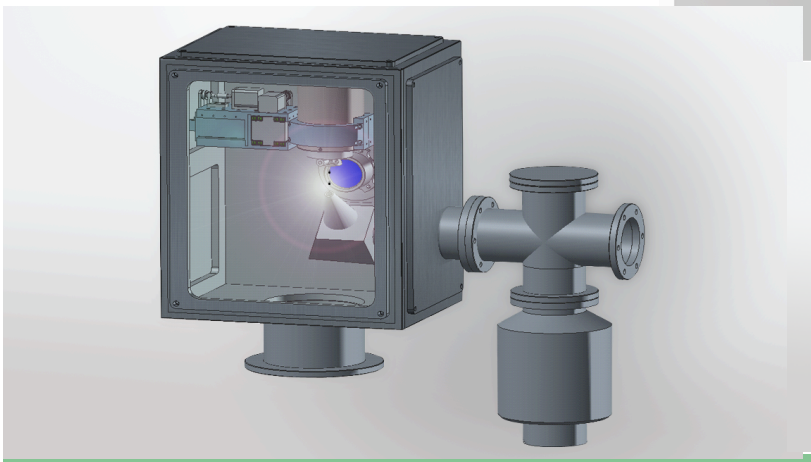
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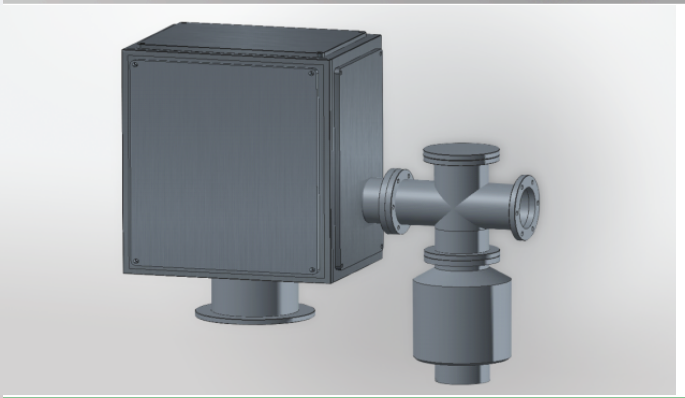
Low power EUV source (LPS)

Controller

- Industrial PC based controller.
- To be finalised after IOs and interface requirements.







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Adlyte: Preliminary Source Specifications

Parameters	Beta Tool (LPS)	Beta Tool (HPS)
Frequency (kHz)	>5	10-20
Pulse Duration (ns)	24	>40
Etendue (mm^2-sr)	$1x10^{-3}$	$5x10^{-3}$
Power at IF (W)	>0.01	>2
Radiance(W/mm^2-sr) at IF	>100	>200
Wavelength (nm)	$13.5^{+}_1\%$	$13.5^{+}_1\%$

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Acknowledgements

ALPS

F. Alickaj, L. Bozinova, A. Giovannini, I. Henderson, B. Newton, B. Rollinger, Prof. N. Chokani and Prof. R. S. Abhari.

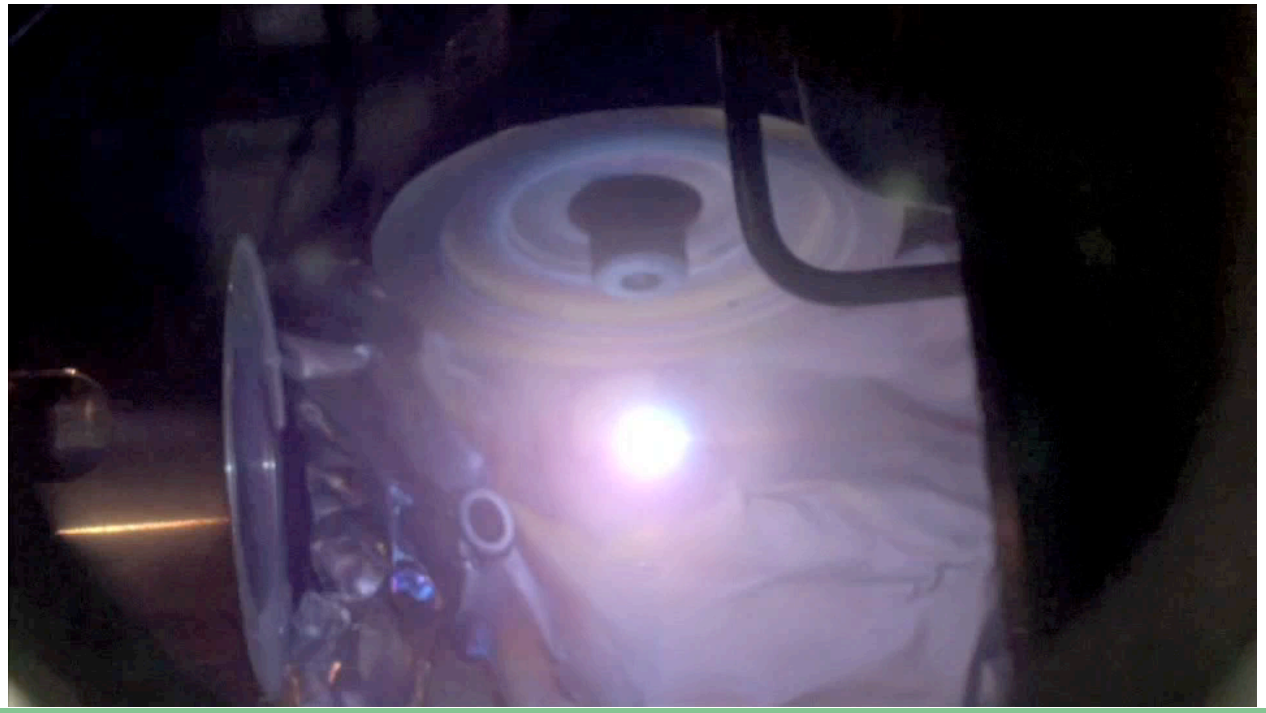
Adlyte Ltd.

Dr. S. Ellwi

Questions

- Thank you for your time.

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- **Adlyte Ltd.: www.adlyte.com**



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